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May 18, 1965

Dr. T. L. K. Smull, Director
Office of Research Grants and Contracts
National Aeronautics and Space Administration
Code SC
Washington 25, D. C.

Dear Dr. Smull:

This letter constitutes the semi-annual status report on the research work supported by NASA under Research Grant NsG 260-62 to the University of Arkansas entitled "Techniques of Radio Frequency Mass Spectrometry", through March 31, 1965.

ION ATTITUDE STUDY

The ion attitude study consists of two areas of investigation. First, the effect of variable energy ions, corresponding to apparent velocities of ions entering an orbiting ion spectrometer, on the mass spectrum is of interest. Secondly, it is necessary to know the effect on the mass spectrum of ions entering an orbiting ion spectrometer at various angles. These studies necessitate the use of a large, highly uniform, nearly parallel, monoenergetic beam of ions whose energy, with respect to the guard ring, is variable. In addition, this beam must impinge upon the guard ring at known, variable angles.

The vacuum chamber, which houses the ion gun and the ion spectrometer tube, allows variation of the ion beam attitude with respect to the guard ring which is on the front of the ion spectrometer tube. At present, ion beam attitude variations are incremental rather than continuous. A dual Teflon O ring seal with differential pumping permits rotation of the ion gun end of the chamber with virtually no change in pressure. With an activated zeolite trap the ultimate pressure in the chamber approaches 1.0×10^{-8} Torr.

The sample (high purity A or N_2) is introduced into the ion gun end of the chamber by a calibrated Granville-Phillips leak. From the high-pressure sample tank there is a high and low pressure regulator feeding a needle valve. The needle valve then supplies the sample through a desiccator at practically constant pressure to a low-pressure indicator and then to the Granville-Phillips leak.

The electron source consists of a 0.010 inch spiral rhenium filament, 7/8" in diameter. To improve mechanical rigidity it is flattened in a plane perpendicular to the axis of the system. A filament shield is used to reduce the number of stray electrons entering the ion system and to increase the efficiency of the electron source. The resulting electron beam is directed towards the ionization region by placing -100 volts potential on the filament relative to the ionizing region. The electrons enter an ionization region of standard configuration but with a large volume for greater ionization efficiency.

The grid which prevents the electrons from proceeding toward the ion spectrometer tube is held at -150 volts relative to the ionizing region. The focusing region for the ion beam consists of three stainless steel cylinders 1/16" apart. The voltages are set so that the density of the beam cross-section at the guard ring is essentially constant.

The characteristics of the ion beam as seen by the guard ring are measured by an aperture assembly, which consists of six concentric, annular conductors in a plane perpendicular to the axis of the system, each of which is insulated from the other. The current collected by any one of the six apertures can then be monitored independently of the others. With the proper voltages on the focusing lens the ion beam density variation between the middle and the outer aperture is within the limits of $\pm 10\%$. To ascertain the parallelism of the beam, the aperture assembly is moved 1/2" on either side of the guard ring position. This results in no appreciable change in the current monitored on the six apertures, indicating that the motion of the particles of the ion beam, for all practical purposes, is parallel.

To measure the energy spread of the ion beam a retarding collector is placed in the ion spectrometer between the guard ring and the 2nd pulling out grid. The retarding curve is found by varying the voltage on the collector and noting the resulting ion current. Taking the derivative of this curve with an analog computer, indicates the energy spread within the ion beam.

The original design on the ion gun has been modified somewhat in an attempt to better meet the severe entrance conditions to an ion spectrometer imposed by satellite environment. An ideal system would be one in which the number of ions reaching the guard ring per unit area (area as viewed by the ion gun) is constant for all ion energies and entrance angles. In other words, as either variable, entrance angle or ion energy, is changed all other voltage and energy relationships external to the ion spectrometer should remain constant.

When varying entrance angle, the only serious problem encountered is having enough ion current available at angles approaching 90^o. Originally an electron emission control grid was placed between the filament and the ionization region for three reasons; to operate the filament in the space charge limited region, to provide more control over the ion beam and, primarily, to increase overall sensitivity. With this control grid installed and at ion attitudes of 90^o, ion beam intensity is sufficient for ion spectrometric analysis. In checking the beam characteristics as seen by the guard ring it was discovered that the energy spread of the ion beam was very large due to the potential gradient between the control grid and the ionization region. To make the ion beam essentially monoenergetic the control grid was removed. The resulting ion beam has an energy spread from three to three and a half volts over the operating range of ion energies.

Originally an attempt was made to approximate an equipotential drift space between the guard ring and the last focusing element of the ion gun. The initial reason was to attempt to eliminate disturbances on the ion beam due to varying field effects as the ion energy was varied. The ideal equipotential drift space is obtained with the last focusing element, chamber and guard ring tied to the same voltage, preferably the ionization region voltage. In this configuration as ion energy is varied, voltage and energy relationships and the number of ions per unit area (area as seen by the ion gun) impinging on the guard ring remain constant. Deviation from ideality is absolutely necessary because if the ionization region and the guard ring are at the same voltage, the energy of the ions passing thru the guard ring is essentially zero for all values of ionization region voltage. Therefore, to give the energy of the ions a reference point the guard ring is tied to true ground. This step is necessary if ion energy variations corresponding to the changing velocity of the satellite between its apogee and perigee are to be simulated. With this configuration it has been established that if ion energy is increased the number of ions per unit area (area as seen by the ion gun) impinging on the guard ring will increase linearly, because of the increasing forces of attraction between the particles in the ion beam and the guard ring. It has also been established that although the number of ions reaching the guard ring varies with ion energy the parallelism, energy spread and density distribution of the ion beam remain virtually unchanged.

The following constitutes the proposed work for the next six months.

Sensitivity and efficiency of the Bennett radio frequency mass spectrometer will be investigated as a function of mass, ion beam energy, and guard ring potential over a range of ion attitudes from 0 to 90 degrees. Included will be a study of any shift in cut-off potential and accelerating potential. All of the spectrometer tube parameters will remain constant and only those external parameters of interest will be varied.

Harmonic ion behavior with respect to the fundamental will be investigated as a function of mass, ion energy and guard ring potential over a range of ion attitudes from 0 to 90 degrees. Any shift in harmonic cutoff due to the above parameters will be included.

Sensitivity and efficiency of the spectrometer will be investigated as a result of changing any of the internal spectrometer tube voltages. This will be performed with all conditions external to the spectrometer, except ion attitude, constant to determine whether the normally accepted voltage values might be optimized for the analysis of ions entering at attitudes other than zero.

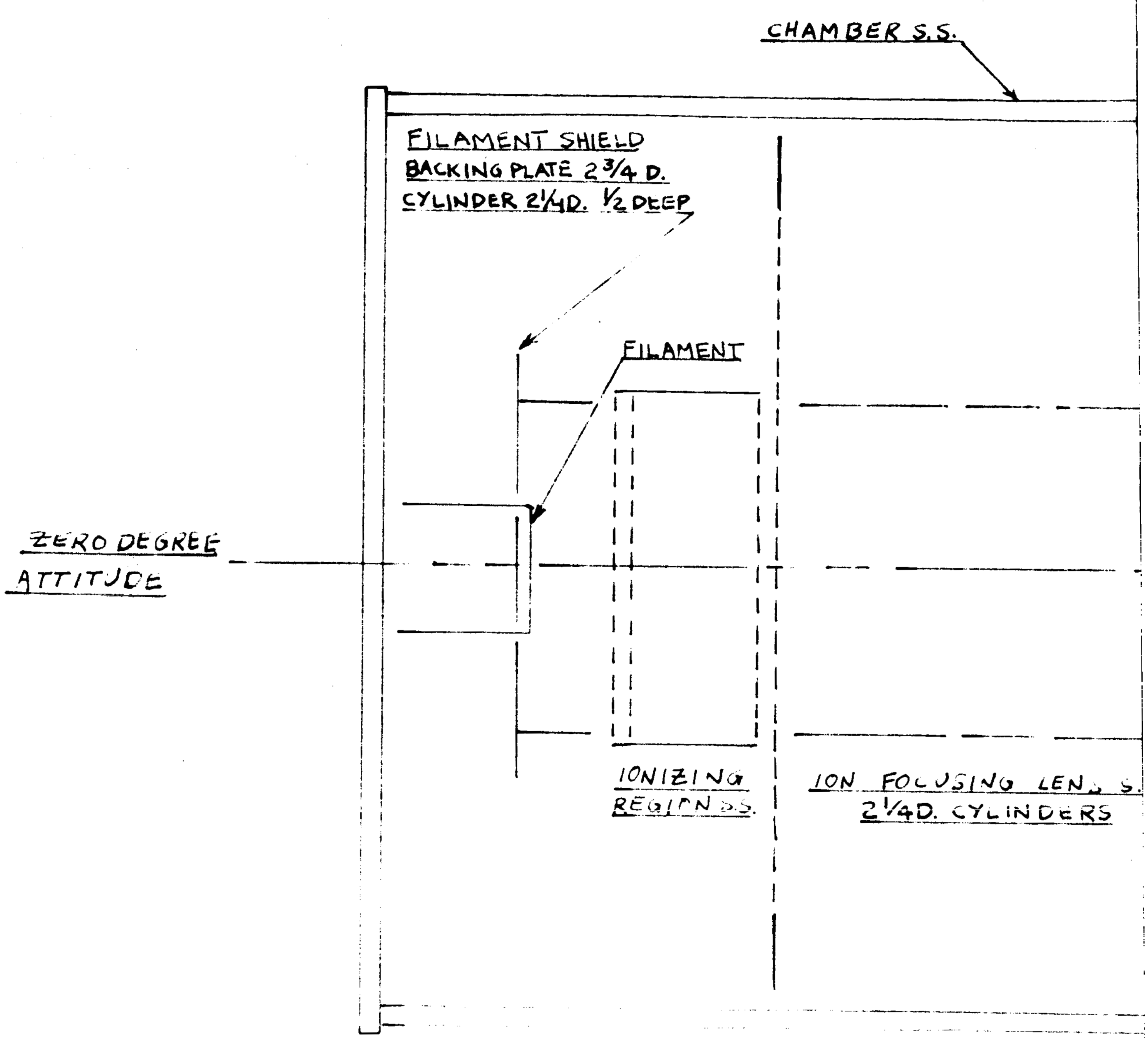
Finally, consultation service will be provided to Goddard Space Flight Center with regard to any related investigations being performed there or at any contractor's site.

Sincerely yours,

M K Testerman

M. K. Testerman
Principal Investigator

MKT/ac


CHAMBER S.S.
FILAMENT SHIELD
BACKING PLATE 2 3/4 D.
CYLINDER 2 1/4 D. 1/2 DEEP
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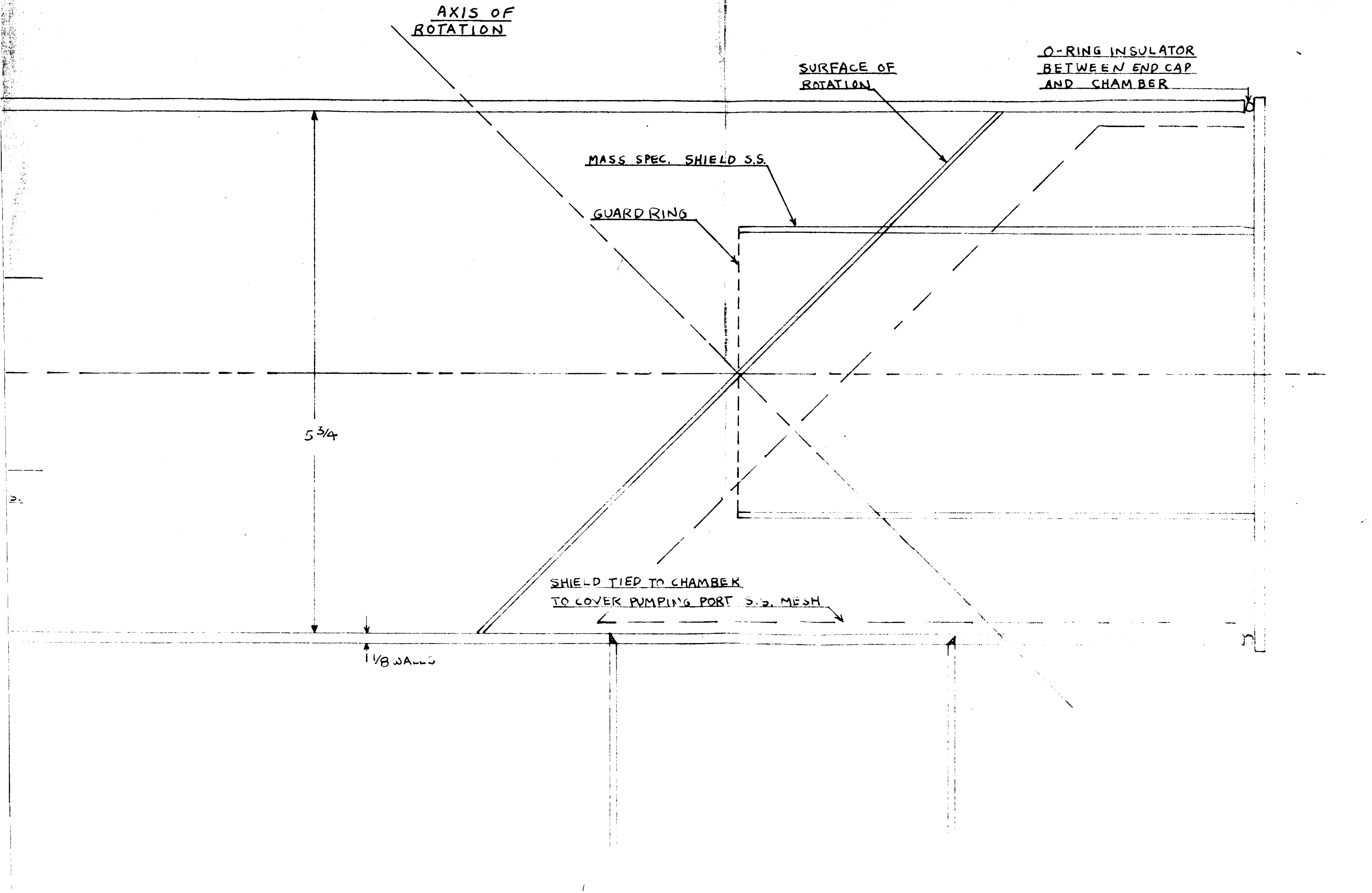
ZERO DEGREE
ATTITUDE
IONIZING
REGION S.S.
ION FOCUSING LENS S.
2 1/4 D. CYLINDERS


AXIS OF ROTATION
SURFACE OF ROTATION
O-RING INSULATOR BETWEEN END CAP AND CHAMBER
MASS SPEC. SHIELD S.S.
GUARD RING
$5\,3/4$
SHIELD TIED TO CHAMBER TO COVER PUMPING PORT S.S. MESH
$1/8$ WALLS